UNIVERSITI SAINS MALAYSIA

First Semester Examination
2013/2014 Academic Session

December 2013 / January 2014

EEE 512/4 – Advanced Digital Signal and Image Processing

Duration : 3 hours

Please check that this examination paper consists of **SEVEN (7)** pages printed before you begin the examination.

Instructions: This question paper consists of **SIX (6)** questions. Answer **FIVE (5)** questions. All questions carry the same marks.

1. (a) Discuss the limiting effect of repeatedly applying a histogram equalisation to a digital image. Hence, explain why the discrete histogram equalisation does not produce flat histogram.

(40 marks)

(b) The gray scale distribution of a poorly contrast image $f(x,y)$ quantised over 3 levels $r_k : k = 0,1,2,\cdots,7$ is tabulated in Figure 1(b).

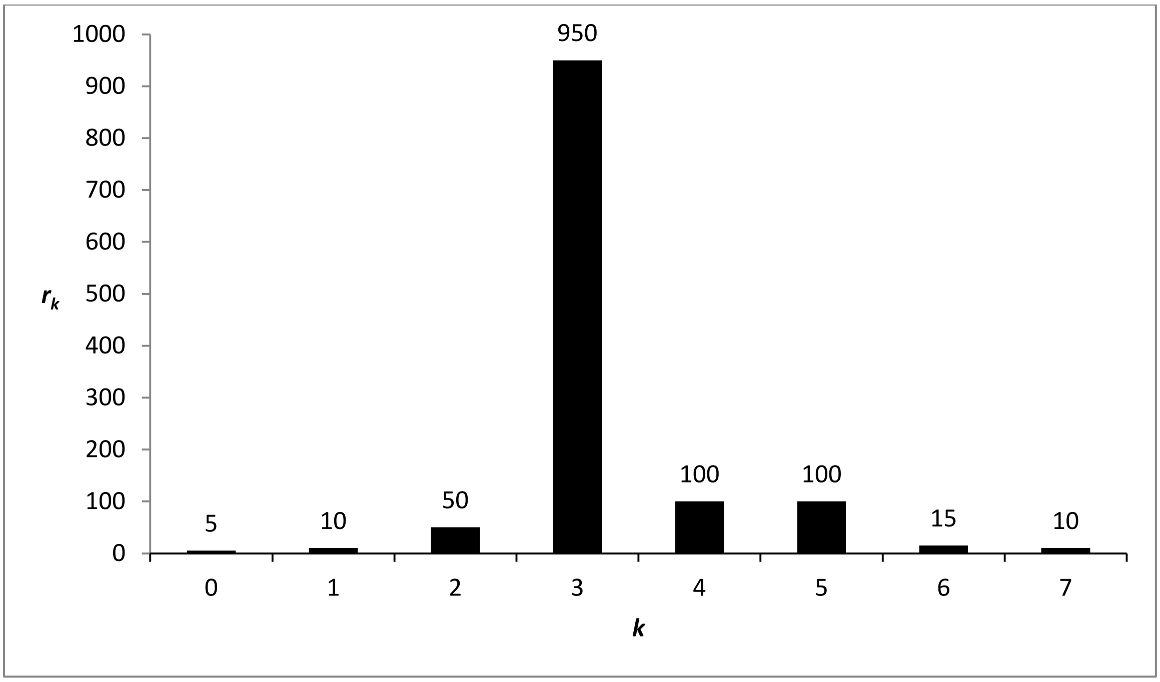


Figure 1(b)

(i) Perform the histogram equalisation on $f(x,y)$ and tabulate the new gray scale distribution.

(20 marks)

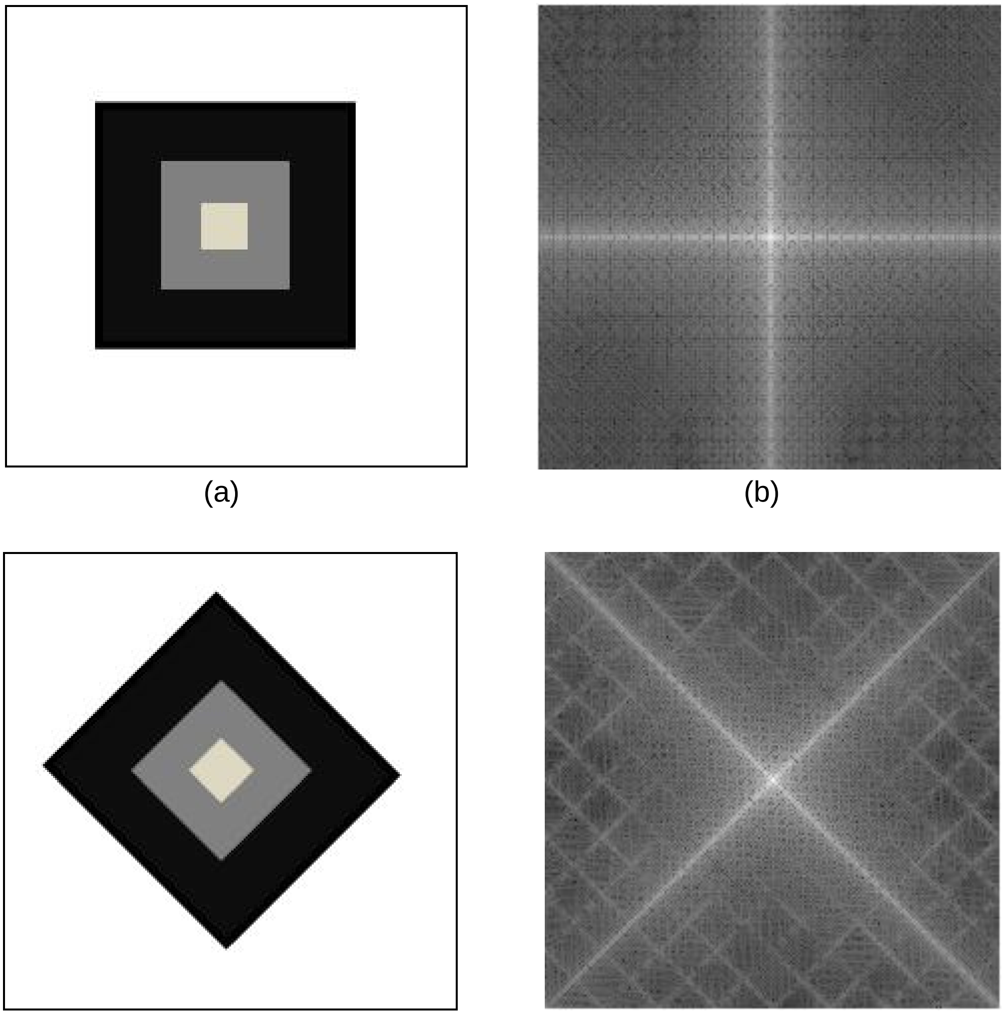
(ii) Histogram processing is suggested on $f(x,y)$ to moderately enhance the dark as well as bright regions, and reduce the mid gray scale region. Suggest the adequate histogram to fulfill these requirements.

(20 marks)

(iii) Using (ii), perform histogram matching on $f(x,y)$ and tabulate the new gray scale distribution.

(20 marks)

2. (a) The images and their corresponding Fourier spectra are shown in Figure 2. Figure 2(b) is the spectrum of Figure 2(a), and Figure 2(d) is the spectrum of Figure 2(c).



(a) (b) (c) (d)

Figure 2

Explain the pattern of each spectrum especially the presence of prominent components along the specific directions.

(40 marks)

(b) A 2-dimensional Laplacian is defined as follows:

$$\begin{bmatrix} 0 & 1 & 0 \\ 1 & -4 & 1 \\ 0 & 1 & 0 \end{bmatrix}$$

(i) Obtain a filter function $H(u,v)$ for performing the Laplacian filtering .in the frequency domain.

(40 marks)

(ii) Show that $H(u,v)$ is a highpass filter.

(20 marks)

<u>Given</u>

$$\Im f\left(x - x_{0,} y - y_{0,}\right) = F(u,v)e^{-j2\pi\left(\frac{ux_0}{M}+\frac{vy_0}{N}\right)}$$
$$2j \sin x = e^{jx} - e^{-jx}$$
$$2\cos x = e^{jx} + e^{-jx}$$
$$2\sin^2 x = 1 - \cos 2x$$

3. (a) Consider a scaling function defined as follows:

$$\varphi(x) = \begin{cases} 1; & 0 \le x < 1.0 \\ 0; & \text{elsewhere} \end{cases}$$

plot $\varphi_{1,0}$ and $\varphi_{1,1}$. Hence show that $\varphi(x)$ obey the fundamental requirement for multiresolution analysis.

(40 marks)

(b) Consider the 1×8 image as follows

$$f(x) = \{4 \quad 2 \quad 6 \quad 6 \quad 6 \quad 3 \quad 2 \quad 1\}$$

(i) draw the require filter bank to implement a first-scale one-dimensional FWT of $f(x)$ and for $j_0 = 1$. Label all inputs and outputs with the proper arrays.

(30 marks)

(ii) use the result from 3(b)(i) to draw the require filter bank to implement the two-dimensional inverse FWT. Label all inputs and outputs with the proper arrays.

(30 marks)

Given:

The wavelet functions are defined as:

$$\psi_{j,k}(x) = 2^{\frac{j}{2}} \psi\left(2^j x - k\right)$$

$$\psi(x) = \sum_n h_\psi(n)\sqrt{2}\varphi(2x - n)$$

$$\psi(x) = \begin{cases} 1 & ; \quad 0 \le x < 0.5 \\ -1 & ; \quad 0.5 \le x < 1.0 \\ 0 & ; \quad \text{elsewhere} \end{cases}$$

The Haar scaling functions are defined as :

$$\varphi(x) = \begin{cases} 1 & ; \quad 0 \le x < 1 \\ 0 & ; \quad \text{elsewhere} \end{cases}$$

$$\varphi_{j,k}(x) = 2^{\frac{j}{2}} \varphi\left(2^j x - k\right)$$

The scaling function coefficients for the Haar function are given by:

$$h_\varphi(n) = \left\{\frac{1}{\sqrt{2}}, \frac{1}{\sqrt{2}}\right\} \quad \text{for} \quad n = 0,1$$

The scaling function coefficients for the Haar wavelet are given by:

$$h_\psi(n) = \left\{\frac{1}{\sqrt{2}}, -\frac{1}{\sqrt{2}}\right\} \quad \text{for} \quad n = 0,1$$

4. (a) A digital signal $x[n]$ is obtained by quantizing an analogue signal $x_a(t) = \sin(2\ \pi t)$. The sampling frequency used is 10 Hz. Find the first four samples of $x[n]$. Assume that the first sampled is taken at time $t = 0$s.

(20 marks)

(b) Express the following length-5 sequence $x[n]$ in terms of unit step sequence $u[n]$.
$x[n] = \{6,4,-2,8,8\}$

(20 marks)

(c) Express $y[n]$ in Figure 1 in terms of $x[n]$.

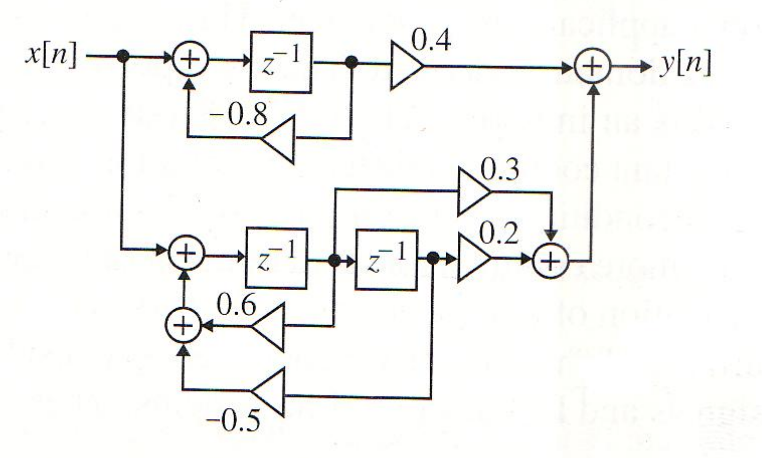


Figure 4(c)

(40 marks)

(d) Determine the period and the average power for the periodic sequence $x[n] = 8 \cos((2\ \pi n/5) + \pi)$.

(20 marks)

5. (a) We want to design an IIR digital filter. The desired passband ripple α_P and the minimum stopband attenuation α_S of that digital filter are 0.05 dB and 40 dB, respectively. Calculate the corresponding peak ripple values δ_P and δ_S.

(20 marks)

(b) Kaiser has developed a simple formula to estimate the FIR digital filter order. The formula is given as:

$$N \cong \frac{-20\log_{10}(\sqrt{\delta_P \delta_S}) - 13}{14.6(\omega_S - \omega_P)/2\pi}$$

Calculate the filter's order by using that equation, if the specifications for the filter are:

- Passband edge F_P = 2 kHz
- Stopband edge F_S = 5 kHz
- Peak passband ripple α_P = 0.1 dB
- Minimum stopband attenuation α_S = 50 dB
- Sampling rate F_T= 20 kHz

Assume that the filter is the Type 2 FIR filter.

(20 marks)

(c) We want to design an IIR Butterworth low pass digital filter $G(z)$. The specifications are: the pass band edge frequency ω_P is 0.25 π, with a pass-band ripple not exceeding 0.5 dB. The minimum stop-band attenuation at the stop-band edge frequency ω_S (0.55 π) is 15 dB. After a few designing steps, we obtained the prototype analog filter $H_a(s)$ as given below:

$$H_a(s) = \frac{0.203451}{(s + 0.588148)\left(s^2 + 0.588148s + 0.345918\right)}$$

By using the simplified bilinear transformation, obtain $G(z)$ and then realize it as a cascade structure.

(60 marks)

6. (a) Find $y[n]$, if $y[n]$ is obtained by convolving $x[n]$ with $h[n]$ (i.e., convolution sum). Given:
$x[n]$ = {1,2,5,4}
$y[n]$ = {9,0,3,1,4,2}

(20 marks)

(b) Realize the following transfer function $H(z)$ in parallel forms II.

$$H(z) = \frac{1.4z^{-1} + 0.3z^{-2} + 0.2z^{-3}}{\left(1 + 0.5z^{-1} + z^{-2}\right)\left(1 - 0.4z^{-1}\right)}$$

(80 marks)

oooOoooo